American Standard
Building Code Requirements
For Masonry

U. S. Department of Commerce

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Miscellaneous Publication 211

UNITED STATES DEPARTMENT OF COMMERCE • Sinclair Weeks, Secretary
NATIONAL BUREAU OF STANDARDS • A. V. Astin, Director

American Standard Building Code Requirements for Masonry

By

Sectional Committee on Building Code Requirements and Good Practice Recommendations for Masonry—A41

Under the Sponsorship of the
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Foreword

This standard is a revision of an earlier edition (1944), and has been approved by the American Standards Association as American Standard Building Code Requirements for Masonry, A41.1–1953. It is a complete code of minimum requirements for masonry construction including definitions, requirements for materials, allowable stresses, and general requirements for all types of masonry except reinforced masonry and thin veneers. This document, prepared by American Standards Association Sectional Committee A41 under the sponsorship of the National Bureau of Standards, is one of a series of building code standards prepared by various committees under the jurisdiction of the Construction Standards Board of the American Standards Association.

A. V. Astin, *Director.*

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American Standard Building Code Requirements for Masonry

By

SECTIONAL COMMITTEE ON BUILDING CODE REQUIREMENTS AND GOOD PRACTICE RECOMMENDATIONS FOR MASONRY—A41

UNDER THE SPONSORSHIP OF THE NATIONAL BUREAU OF STANDARDS

Abstract

This standard is a revision of an earlier edition (1944), and has been approved by the American Standards Association as American Standard Building Code Requirements for Masonry, A41.1–1953. It is a complete code of minimum requirements for masonry construction including definitions, requirements for materials, allowable stresses, and general requirements for all types of masonry except reinforced masonry and thin veneers. This document, prepared by American Standards Association Sectional Committee A41 under the sponsorship of the National Bureau of Standards, is one of a series of building code standards prepared by various committees under the jurisdiction of the Construction Standards Board of the American Standards Association. The basis of the requirements of this standard, together with examples of good practice, is discussed in an appendix.

Section 1. General

1.1. **Scope.** This standard covers requirements suitable for use in building codes, applying to the design and construction of masonry in building construction. It does not include requirements for reinforced concrete, reinforced gypsum concrete, or reinforced masonry,[1] nor requirements concerning fire protection.

1.2. **Application of Requirements.** Masonry construction in any building or other structure shall conform to these requirements.

1.3. **Dimensions.** Unless the word "actual" is used, the dimensional requirements for masonry given in this standard are nominal, and apply to such dimensions as minimum thicknesses and heights of walls. The measured dimensions of the masonry may be less than the required nominal dimensions by the thickness of one mortar joint, but not more than one-half inch, and by the amount of the dimensional tolerance permitted by specifications applying to units used in the construction. (Appendix 1.3.)

1.4. **Alternate Materials and Constructions.** Masonry materials and methods of construction not specifically authorized by these requirements may be permitted in accordance with the provisions of the building code.

1.5. **Tests.**

1.5.1. ***When Required.*** Whenever there is insufficient evidence that any material or construction conforms to these requirements, or there is insufficient evidence to substantiate claims for alternate

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[1] See American Standard Building Code Requirements for Reinforced Concrete (ACI 318–51, ASA A89.1–51), and American Standard Building Code Requirements for Reinforced Gypsum Concrete, ASA A59.1–[illegible]5. A proposed standard for reinforced masonry is under development in Sectional Committee A41.

materials or construction, the building official may require tests as proof of compliance to be made at the expense of the applicant by an approved agency.

1.5.2. ***Methods.*** Tests of masonry materials shall be made in accordance with generally recognized standards. Strength tests of masonry constructions shall be made in accordance with the Tentative Methods of Conducting Strength Tests of Panels for Building Construction, ASTM E 72–51 T. Duly authenticated tests by a competent person or laboratory may be accepted by the building official in lieu of tests under his own supervision. (See Appendix 2.)

1.5.3. ***Compressive Stresses.*** Allowable compressive stresses in alternate constructions shall not exceed one-fourth of the average compressive strength of representative specimens of the proposed construction as determined by responsible authorities.

1.6. **Definitions.** Unless otherwise expressly stated, the following terms shall, for the purpose of this standard, have the meanings indicated in this section. Where terms are not defined in this section, they shall have their ordinarily accepted meanings, or such as the context may imply.

1.6.1. ***Abbreviations.***

ACI. American Concrete Institute, 18263 W. McNichols Rd., Detroit 19, Mich.

ASA. American Standards Association, Incorporated, 70 East 45th Street, New York 17, N. Y.

ASTM. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

psi. Pounds per square inch.

1.6.2. ***Approved.*** Approved by the building official or other authority having jurisdiction.

1.6.3. ***Architectural Terra Cotta.*** Plain or ornamental (molded or extruded) hard-burned building units, usually larger in size than brick, consisting of mixtures of plastic clays, fusible minerals, and grog, and having a glazed or unglazed ceramic finish.

1.6.4. ***Ashlar Facing.*** Facing of a faced or veneered wall composed of solid rectangular units usually larger in size than brick, having sawed, dressed, or squared beds, and mortar joints.

1.6.5. ***Ashlar Masonry.*** Masonry composed of rectangular units usually larger in size than brick and properly bonded, having sawed, dressed, or squared beds, and mortar joints.

1.6.6. ***Bonder (Header).*** A masonry unit which ties two or more wythes (leaves) of the wall together by overlapping, such as a header.

1.6.7. ***Brick.*** A solid masonry unit having a shape approximately a rectangular prism, usually not larger than 4 by 4 by 12 inches. A brick may be made of burned clay or shale, of fire clay or mixtures thereof, of lime and sand, of cement and suitable aggregates, or of other approved materials.

1.6.8. ***Building.*** A structure enclosed within a roof and within exterior walls or fire walls designed for the housing, shelter, enclosure and support of individuals, animals or property of any kind.

1.6.9. ***Building Official.*** The officer or other designated authority charged with the administration and enforcement of the building code, or his duly authorized representative.

1.6.10. ***Concrete.*** A mixture of portland cement, aggregates and water. (See 1.6.20 and 2.3.)

1.6.11. ***Cross-sectional Area.*** Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cores or cellular space. Gross cross-sectional area of scored units shall be determined to the outside of the scoring but the cross-sectional area of the grooves shall not be deducted from the gross cross-sectional area to obtain the net cross-sectional area.

1.6.12. ***Grout*** (see Mortar).

1.6.13. ***Grouted Masonry.*** Grouted masonry is masonry in which the interior joints are filled by pouring grout therein as the work progresses.

1.6.14. ***Header*** (see Bonder).

1.6.15. ***Height of Wall.*** The vertical distance from the foundation wall or other immediate support of such wall, to the top of the wall.

1.6.16. ***Hollow Masonry Unit.*** A masonry unit whose net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane. (See Cross-sectional Area.)

1.6.17. ***Leaf*** (***leaves***). (See Wythe.)

1.6.18. ***Masonry.*** A built-up construction or combination of building units of such materials as clay, shale, concrete, glass, gypsum, or stone, set in mortar; or plain concrete.

1.6.18.1. Masonry of Hollow Units. Masonry consisting wholly or in part of hollow masonry units laid contiguously in mortar.

1.6.18.2. Solid Masonry. Masonry consisting wholly of solid masonry units laid contiguously in mortar, or consisting of plain concrete.

1.6.19. ***Mortar.*** A plastic mixture of cementitious materials, fine aggregates and water used to bond masonry or other structural units. Mortar of pouring consistency is termed grout.

1.6.20. ***Partition.***

1.6.20.1. Nonbearing Partition. An interior nonbearing wall one story or less in height.

1.6.21. ***Pier.*** An isolated column of masonry. A bearing wall not bonded at the sides into associated masonry shall be considered a pier when its horizontal dimension measured at right angles to the thickness does not exceed four times its thickness.

1.6.22. ***Required.*** Means required by this standard.

1.6.23. ***Rubble.***

1.6.23.1. Coursed Rubble. Masonry composed of roughly shaped stones fitting approximately on level beds, well bonded, and brought at vertical intervals to continuous level beds or courses.

1.6.23.2. Random Rubble. Masonry composed of roughly shaped stones, well bonded and brought at irregular vertical intervals to discontinuous but approximately level beds or courses.

1.6.23.3. Rough or Ordinary Rubble. Masonry composed of nonshaped or field stones laid without regularity of coursing.

1.6.24. ***Solid Masonry Unit.*** A masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is 75 percent or more of its gross cross-sectional area measured in the same plane. (See Cross-sectional Area.)

1.6.25. ***Story.*** That portion of a building included between the upper surface of any floor and the upper surface of the floor next above, except that the topmost story shall be that portion of a building in-

cluded between the upper surface of the topmost floor and the ceiling or roof above.

1.6.26. ***Walls.***

1.6.26.1. Bearing Wall. A wall which supports any vertical load in addition to its own weight.

1.6.26.2. Cavity Wall (Core Wall). (See Hollow Wall.)

1.6.26.3. Faced Wall. A wall in which the masonry facing and the backing are of different materials and are so bonded as to exert a common reaction under load.

1.6.26.4. Foundation Wall. A wall below the floor nearest grade serving as a support for a wall, pier, column, or other structural part of a building.

1.6.26.5. Hollow Wall. A wall of masonry so arranged as to provide an air space within the wall between the inner and outer parts (wythes) of the wall.

1.6.26.5.1. *Cavity Wall* (*Core Wall*). A wall built of masonry units or of plain concrete, or a combination of these materials, so arranged as to provide an air space within the wall (with or without insulating material), and in which the inner and outer wythes of the wall are tied together with metal ties.

1.6.26.5.2. *Masonry Bonded Hollow Wall.* A hollow wall built of masonry units in which the inner and outer wythes of the wall are bonded together with masonry units, such as in the all-rolok and rolok-bak walls.

1.6.26.6. Nonbearing Wall. A wall which supports no vertical load other than its own weight.

1.6.26.7. Parapet Wall. That part of any wall entirely above the roof.

1.6.26.8. Party Wall. A wall on an interior lot line used or adapted for joint service between two buildings.

1.6.26.9. Veneered Wall. A wall having a facing of masonry or other material securely attached to the backing, but not so bonded as to exert a common reaction under load.

1.6.27. ***Wythe*** (***Leaf***). Each continuous vertical section of a wall one masonry unit in thickness and tied to its adjacent vertical section or sections (front or back) by bonders (headers), metal ties or grout.

Section 2. Materials

(See Appendix 2)

2.1. **Quality.** Materials used in masonry shall be of good quality conforming to generally accepted good practice. Except as may be otherwise provided herein, the standards [2] and requirements set forth in Section 2.2, Standards of Quality, shall be deemed to represent generally accepted good practice in building construction. (See Section 1.5.2.)

2.1.1. ***Secondhand Materials.*** Secondhand materials shall not be used in masonry unless such materials conform to these requirements and have been thoroughly cleaned. (See Appendix 2.1.1.)

2.2. **Standards of Quality.**

2.2.1. ***Building Brick.*** (See Appendix 2.2.1.)

[2] Since national standards are revised at frequent intervals, references should be made to the latest edition in incorporating these standards in a local code.

2.2.1.1. Brick and Solid Clay or Shale Masonry Units. Standard Specifications for Building Brick (Solid Masonry Units Made from Clay or Shale) ASTM C 62–50.

2.2.1.2. Sand-Lime Brick. American Standard Specifications for Sand-Lime Building Brick (ASTM C 73–51; ASA A78.1–1952).

2.2.1.3. Concrete Brick. American Standard Specifications for Concrete Building Brick (ASTM C 55–52; ASA A75.1–1953).

2.2.1.4. Grades. Clay, shale, or sand-lime brick subject to the action of weather or soil, but not subject to frost action when permeated with water, shall be of Grade MW or Grade SW, and when subject to temperature below freezing while in contact with the soil shall be of Grade SW; concrete brick subject to the action of weather or soil shall be of Grade A.

Note.—In localities where brick conforming in physical properties to the requirements of this specification are not readily obtainable, the use of other brick should be permitted, if suitable evidence of strength and resistance to weathering is presented to the building official.

2.2.2. ***Structural Clay Tile and Hollow Clay or Shale Masonry Units.***

2.2.2.1. Load-Bearing Wall Tile. American Standard Specifications for Structural Clay Load-Bearing Wall Tile (ASTM C 34–52; ASA A74.1–1953). Structural clay tile subject to the action of weather or soil shall be of Grade LBX, or, if used for load-bearing purposes but not subject to the action of weather or soil, of Grade LB or Grade LBX of this specification.

2.2.2.2. Nonload-Bearing Tile. American Standard Specifications for Structural Clay Nonload-Bearing Tile (ASTM C 56–52; ASA A76.1–1953).

2.2.3. ***Concrete Masonry Units*** (See Appendix 2.2.3.)

2.2.3.1. Hollow Load-Bearing Units. American Standard Specifications for Hollow Load-Bearing Concrete Masonry Units (ASTM C 90–52; ASA A79.1–1953), for hollow units in load-bearing masonry or subject to the action of weather or soil.

2.2.3.2. Hollow Nonload-Bearing Units. American Standard Specifications for Hollow Nonload-Bearing Concrete Masonry Units (ASTM C 129–52; ASA A80.1–1953), for hollow units used in nonload-bearing masonry not subject to the action of weather or soil.

2.2.3.3. Solid Load-Bearing Units. American Standard Specifications for Solid Load-Bearing Concrete Masonry Units (ASTM C 145–52; ASA A81.1–1953). Solid units subject to the action of weather or soil shall be Grade A.

2.2.4. ***Stone.***

2.2.4.1. Cast Stone. Specification for Cast Stone, ACI 704–44.

2.2.4.2. Natural Stone. Stone used in masonry shall be sound, free from friable inclusions and have sufficient strength, durability, resistance to impact and abrasion for the proposed use. (See Appendix 2.2.4.2.)

2.2.5. ***Architectural Terra Cotta.*** Architectural terra cotta shall have a strong homogeneous body and shall conform to the applicable requirements of Sections 2.2.1.1 and 2.2.2. All units shall have the necessary anchor holes and shall be so formed as to engage properly with the supporting structure.

2.2.6. ***Glazed Building Units.*** Units shall conform to the applicable requirements of the specifications for hollow or solid clay masonry units of Sections 2.2.1.1 and 2.2.2.

2.2.7. ***Glass Block.*** Block may be solid or hollow; mortar bearing surfaces of the blocks shall be provided with a surface or a coating material to afford adhesion between mortar and block.

2.2.8. ***Gypsum Tile and Block.*** Standard Specifications for Gypsum Partition Tile or Block, ASTM C 52–41.

2.2.9. ***Cementitious Materials.***

Gypsum, (ASTM C 22–50; ASA A49.1–1951).

Hydrated Lime for Masonry Purposes, ASTM C 207–49.

Hydraulic Hydrated Lime for Structural Purposes, ASTM C 141–42.

Quicklime for Structural Purposes, ASTM C 5–26.

Masonry Cement, ASTM C 91–52T. (See footnote 3 in Appendix 6.1)

Natural Cement, ASTM C 10–52T.

Portland Cement, ASTM C 150–52.

Air-Entraining Portland Cement, ASTM C 175–51 T.

Portland Blast Furnace Cement, ASTM C 205–51 T.

2.2.10. ***Aggregate for Mortar.*** Standard Specifications for Aggregate for Masonry Mortar, ASTM C 144–52T.

2.2.11. ***Aggregate for Concrete.*** Standard Specifications for Concrete Aggregates, ASTM C 33–52T or Standard Specifications for Lightweight Aggregates for Concrete, ASTM C 130–42; other aggregates may be approved which have been shown by test or experience to be satisfactory for the intended purpose.

2.2.12. ***Water.*** Water shall be clean, and free from injurious amounts of oils, acids, alkalis, organic materials, or other deleterious substances.

2.3 Plain Concrete

2.3.1. The requirements for concrete in Building Code Requirements for Reinforced Concrete (ACI 318–51; ASA A89.1–1951) shall be deemed to describe the generally accepted good practice in plain concrete construction.

2.3.2. Concrete exposed to freezing temperature shall have an effective mixing water content of not more than 6 gal per sack of cement (53 lb per 100 lb of cement). Concrete exposed to the ground or the weather, except in arid regions, shall have an effective mixing water content of not more than 7½ gal per sack of cement (66 lb per 100 lb of cement). These requirements may be waived if adequate tests or experience show that concrete with a higher water content gives satisfactory durability and protection of reinforcement under the prevailing conditions. Cellular concrete or concrete made with light weight aggregate and used under conditions not subject to ground or weather exposure, shall have a compressive strength of at least 60[illegible] psi at the age of 28 days, and that for floor or roof fill, a strength of at least 150 psi. The strength of the concrete for all conditions shall be such that the allowable stresses determined as in Section 4.2.3 are not exceeded. (See Appendix 2.3.2.)

Section 3. Mortar

3.1. **Quality.** Mortar shall conform to the requirements of ASTM Tentative Specifications for Mortar for Unit Masonry, ASTM Designation C 270–52T. (See Appendix 3.1 including footnote 5.)

3.2. **Grout.** Grout shall be Type A–1, Type A–2, or Type B mortar as defined in ASTM C 270–52T to which is added water to produc[illegible]

consistency for pouring without segregation of constituents of the mortar. Type A–1 grout shall be used with Type A–1 mortar; either Type A–1 or Type 2–A grout shall be used with Type A–2; Type A–1, Type A–2 or Type B grout shall be used with Type B mortar.

3.3. **Gypsum Mortar.** Gypsum mortar shall be composed by weight of one part of gypsum and not more than three parts of mortar aggregate.

3.4. **Types of Mortar Permitted.** Masonry shall be laid in mortar of the types specified in table 1. (See Appendix 3.4.)

TABLE 1.

Kind of masonry	Types of mortar permitted
Foundations:	
Footings	A–1, or A–2
Walls of solid units	A–1, A–2 or B
Walls of hollow units	A–1 or A–2
Hollow walls	A–1 or A–2
Masonry other than foundation masonry:	
Piers of solid masonry	A–1, A–2 or B
Piers of hollow units	A–1 or A–2
Walls of solid masonry	A–1, A–2, B or C
Walls of solid masonry, other than parapet walls or rubble stone walls, not less than 12 inches thick nor more than 35 feet in height, supported laterally at intervals not exceeding 12 times the wall thickness.	A–1, A–2, B, C, or D
Walls of hollow units; load-bearing or exterior, and hollow walls 12 in. or more in thickness.	A–1, A–2 or B
Hollow walls, less than 12 in. in thickness where assumed design wind pressure: [a]	
(a) exceeds 20 pounds per sq ft	A–1 or A–2
(b) does not exceed 20 pounds per sq ft	A–1, A–2 or B
Glass block masonry	A–1, A–2 or B
None-bearing partitions of fire-proofing composed of structural clay tile or concrete masonry units.	A–1, A–2, B, C, or gypsum.
Gypsum partition tile or block	Gypsum
Fire brick	Refractory air setting mortar
Linings of existing masonry, either above or below grade	A–1 or A–2
Masonry other than above	A–1, A–2 or B

[a] For design wind pressures, consult American Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, ASA A58.1.

Section 4. Allowable Stresses

4.1. **General.** In determining the stresses in the masonry, the effects of all loads and conditions of loading and the influence of all forces affecting the design and strength of the several parts shall be taken into account. Stresses shall be calculated on actual rather than nominal dimensions. Masonry construction shall be so designed and constructed that the allowable stresses prescribed herein are not exceeded.

4.2. **Allowable Stresses.** Except as permitted in other sections of this standard, the compressive stresses in masonry shall not exceed the values given in table 2.

TABLE 2. *Allowable compressive stresses in unit masonry*

(See Appendix 4.2.)

Construction; grade of unit	Allowable compressive stresses gross cross-sectional area (except as noted)				
	Type A–1 mortar	Type A–2 mortar	Type B mortar	Type C mortar	Type D mortar
Solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:	*psi*	*psi*	*psi*	*psi*	*psi*
8,000 plus, psi	400	350	300	200	100
4,500 to 8,000, psi	250	225	200	150	100
2,500 to 4,500, psi	175	160	140	110	75
1,500 to 2,500, psi	125	115	100	75	50
Grouted [a] solid masonry of brick and other solid units of clay or shale; sand-lime or concrete brick:					
4,500 plus, psi	350	275	200	------	------
2,500 to 4,500, psi	275	215	155	------	------
1,500 to 2,500, psi	225	175	125	------	------
Solid masonry of solid concrete masonry units:					
Grade A	175	160	140	100	------
Grade B	125	115	100	75	------
Masonry of hollow units	85	75	70	------	------
Piers of hollow units, cellular spaces filled, as in Sec. 5.3	105	95	90	------	------
Hollow walls (cavity or masonry bonded).[b] Solid units:					
Grade A or 2,500, psi plus	140	130	110	------	------
Grade B or 1,500 to 2,500, psi	100	90	80	------	------
Hollow units	70	60	55	------	------
Stone ashlar masonry:					
Granite	800	720	640	500	------
Limestone or marble	500	450	400	325	------
Sandstone or cast stone	400	360	320	250	------
Rubble stone, coursed, rough or random	140	120	100	80	------

[a] See Section 3.2.

[b] On gross cross-sectional area of wall minus area of cavity between wythes (leaves). The allowab[le] compressive stresses for cavity walls are based upon the assumption that the floor loads bear upon but 1 [of] the 2 wythes. When hollow walls are loaded concentrically, the allowable stresses may be increased [by] 25 percent.

4.2.1. ***Higher Stresses.*** Higher stresses than herein specifie[d] may be used, but only if it is clearly established to the satisfactio[n] of the building official, by test, or other approved evidence, th[at] material of a higher grade or a superior workmanship than is general[ly] provided in accepted practice will be employed under approv[ed] inspection. The use of higher stresses, however, shall not be allow[ed] until a statement giving the reasons for such permission togeth[er]

with the facts and circumstances on which it is based, has been placed on file and made a part of the official record of the permit. (See Appendix 4.2.1 for effect of workmanship.)

4.2.2. ***Composite Walls.*** In composite walls or other structural members composed of different kinds or grades of units or mortars, the maximum stress shall not exceed the allowable stress for the weakest of the combinations of units and mortars of which the member is composed. (See Appendix 4.2.2.)

4.2.3. ***Allowable Stresses in Plain Concrete.*** The allowable stresses shall not exceed 25 percent for compression, and 3 percent for tension in extreme fibre in flexure, of the compressive strength of the concrete. When the ratio of height to thickness of structural members of plain concrete exceeds 10, the percentage for compressive stress shall be reduced proportionately to 18 percent for a ratio of height to thickness of 20. For hollow (cavity) walls of plain concrete, the allowable stress shall not exceed 20 percent of the compressive strength of the concrete based upon the gross cross-sectional area of wall minus area of cavity. (See Appendix 4.2.)

Section 5. Lateral Support

5.1. **Ratio of Height or Length to Thickness.** The ratio of unsupported height to nominal thickness or the ratio of unsupported length to nominal thickness (one or the other but not necessarily both) for solid masonry walls or bearing partitions of buildings shall not exceed 20 if of plain concrete or of solid masonry units if laid in Type A–1, A–2, B or C mortar, nor 12 if laid in Type D mortar; and, regardless of the type of permitted mortar used, shall not exceed 18 for walls of hollow masonry units or hollow walls. In computing the ratio for cavity walls, the value for thickness shall be the sum of the nominal thicknesses of the inner and outer wythes. In walls composed of different kinds or classes of units or mortars, the ratio of height or length to thickness shall not exceed that allowed for the weakest of the combination of units and mortars of which the member is composed. See Section 9.2 for veneers. For completed cantilever walls of masonry the precautions of Section 11.9.1 shall be followed. (See Appendix 5.1.)

.2. **Method of Support.** Lateral support may be obtained by cross walls, piers, or buttresses, when the limiting distance is measured horizontally, or by floors and roofs when the limiting distance is measured vertically. Sufficient bonding or anchorage shall be provided between the walls and the supports to resist the assumed wind or other horizontal force, acting either inward or outward. Piers, buttresses and cross walls relied upon for lateral support shall have sufficient strength and stability to transfer the horizontal force, acting in either direction to adjacent structural members or to the ground. When walls are dependent upon floors or roofs for their lateral support, provision shall be made in the building to transfer the lateral forces to the ground.

.3. **Piers.** The unsupported height of piers shall not exceed 10 times their least dimension provided that when structural clay tile or hollow concrete units are used for isolated piers to support beams or girders, their unsupported height shall not exceed 4 times their least dimension unless the cellular spaces are filled solidly with concrete or either type A–1 or A–2 mortar.

Section 6. Thickness of Masonry

(See Appendix 6)

6.1. **General.** The thickness of masonry walls shall conform to the requirements of this Section and of Section 5, provided that the allowable stresses in Section 4.1 and 4.3 shall not be exceeded.

6.1.1. ***Change in Thickness.***

6.1.1.1. Variation in Thickness. Except for window-paneled backs, and permissible chases and recesses, walls shall not vary in thickness between their lateral supports. When a change in thickness, due to minimum thickness requirements, occurs between floor levels, the greater thickness shall be carried up to the higher floor level.

6.1.1.2. Decrease in Thickness. Where walls of masonry of hollow units or masonry bonded hollow walls are decreased in thickness a course or courses of solid masonry shall be interposed between the wall below and the thinner wall above, or special units or construction shall be used that will adequately transmit the loads from the shells above to those below.

6.2. **Thickness of Bearing Walls.**

6.2.1. ***Minimum Thickness.*** The thickness of masonry bearing walls shall be at least 12 inches for the uppermost 35 feet of their height, and shall be increased 4 inches for each successive 35 feet or fraction thereof measured downward from the top of the wall, except as otherwise permitted in Section 6.2.3, Exceptions.

6.2.2. ***Rubble Stone Walls.*** Rough or random or coursed rubble stone walls shall be 4 inches thicker than is required by Section 6.2.1 but in no case less than 16 inches thick. The exceptions of Section 6.2.3 shall not apply to rubble stone walls.

6.2.3. ***Exceptions.***

6.2.3.1. Stiffened Walls. Where solid masonry bearing walls are stiffened at distances not greater than 12 feet apart by masonry cross walls or by reinforced concrete floors, they may be of 12-inch thickness for the uppermost 70 feet, measured downward from the top of the wall, and shall be increased 4 inches in thickness for each successive 70 feet or fraction thereof.

6.2.3.2. Top Story Walls. The top story bearing wall of a building not exceeding 35 feet in height may be of 8-inch thickness provided it is not over 12 feet in height and the roof construction imparts no lateral thrust to the walls.

6.2.3.3. Walls of Residence Buildings. In residence buildings not more than 3 stories in height, walls other than coursed or rough or random rubble stone walls, may be of 8-inch thickness when not over 35 feet in height and the roof is designed to impart no horizontal thrust. Such walls in 1-story residence buildings, and 1-story private garages, may be of 6-inch thickness when not over 9 feet in height, except that the height to the peak of a gable may be 15 feet.

6.2.3.4. Penthouses and Roof Structures. Masonry walls above roof level, 12 feet or less in height, enclosing stairways, machinery rooms, shafts, or penthouses, may be of 8-inch thickness and may be considered as neither increasing the height nor requiring any increase in the thickness of the wall below.

6.2.3.5. Walls of Plain Concrete. Plain concrete walls may be 2 inches less in thickness than required by Section 6.2, but not less than 8 inches, except 6-inch walls as permitted by Section 6.2.3.3. (See Section 7.4.)

6.2.3.6. Hollow Walls (Cavity or Masonry Bonded). Hollow walls shall not exceed 35 feet in height except that 10-inch cavity walls shall not exceed 25 feet in height above the support of such walls. The facing and backing of cavity walls shall each have a thickness of at least 4 inches and the cavity shall be not less than 2 inches (actual) nor more than 3 inches in width.

6.2.3.7. Faced Walls. Neither the height of faced (composite) walls nor the distance between lateral supports shall exceed that precribed for masonry of either of the types forming the facing or the backing.

.3. Thickness of Nonbearing Walls and Partitions.

6.3.1. ***Nonbearing Walls.*** Nonbearing exterior masonry walls nay be 4 inches less in thickness than required for bearing walls, but he thickness shall be not less than 8 inches except where 6-inch walls re specifically permitted.

6.3.2. ***Nonbearing Partitions.*** The distance between lateral ipports of nonbearing partitions of masonry shall not exceed 36 mes the actual thickness of the partition including plaster. See ection 5.2. (See Appendix 6.3.2.)

6.3.3. ***Gypsum Tile and Block.*** Gypsum partition tile or block iall not be used in bearing walls, or where subject to continuous ampness. Gypsum partition tile shall not be used for partitions to ceive portland cement plaster, ceramic tile, marble or structural ass wainscots unless self-furring metal lath is placed over the gypsum le.

4. Foundation Walls. (See Appendix 6.4.)

6.4.1. ***Thickness.*** Foundation walls shall be of sufficient strength id thickness to resist lateral pressures from adjacent earth and to pport their vertical loads without exceeding the allowable stresses. oundation walls or their footings shall extend below the level of ost action and shall be not less in thickness than the walls immediely above them except as provided in Section 6.4.2.5. Foundation alls shall be at least 12 inches thick except as noted in Section 6.4.2, xceptions. (See Appendix 6.4.1.)

6.4.2. ***Exceptions.***

6.4.2.1. Reinforced Masonry. Foundation walls of masonry its supported laterally at vertical intervals not exceeding 12 feet ay be 8 inches thick if reinforced by means of vertical ⅝-inch diamer deformed reinforcing bars (or their equivalent) spaced not more an 12 inches apart and not less than 3½ inches from the pressure side the wall; or ½-inch diameter deformed reinforcing bars (or their uivalent) spaced not more than 24 inches apart and not less than nches from the pressure side of the wall. Reinforcing bars shall end from footing to top of foundation wall. Bars shall be lapped least 30 diameters at splices. The space between each bar and adjacent enclosing masonry surfaces shall be solidly filled with pe A–1 grout or mortar. (See Appendix 6.4.2.1.)

6.4.2.2. Allowable Depth of 8-Inch Foundation Walls. id foundation walls of solid masonry units or of coursed stone that

do not extend more than 5 feet below the adjacent finished ground level may be 8 inches in thickness; cavity walls and walls of hollow units that do not extend more than 4 feet below the adjacent finished ground level, may be 10 inches and 8 inches, respectively, in thickness. Those depths may be increased to a maximum of 7 feet with the approval of the building official when he is satisfied that soil conditions warrant such increase. The combined height of an 8-inch foundation wall and the wall supported shall not exceed the height permitted for 8-inch walls. (See Appendix 6.4.1.)

6.4.2.3. Rubble Stone. Foundation walls of rubble stone shall be at least 16 inches thick. Rough or random rubble shall not be used as foundations for walls exceeding 35 feet in height.

6.4.2.4. Plain Concrete. Foundation walls of cast-in-place concrete shall be at least 8 inches thick; provided that when the basement floor does not exceed 4 feet below average grade level, such walls may be 6 inches thick.

6.4.2.5. Foundation Walls Supporting Brick Veneer or Cavity Walls. Foundation walls of 8-inch thickness and conforming to the provisions of this section may be used as foundations for dwellings with walls of brick veneer on frame walls, or with 10-inch cavity walls; provided that the dwelling is not more than 1½ stories in height and the total height of the wall, including the gable, is not more than 20 feet. Foundation walls of 8-inch thickness supporting brick veneer or cavity walls shall be corbelled with solid units to provide a bearing the full thickness of the wall above unless adequate bearing is provided by a concrete floor slab. The total projection shall not exceed 2 inches with individual corbels projecting not more than ⅓ the depth (height) of the unit. The top corbel course shall be not higher than the bottom of floor joists and shall be a full header course of headers at least 6 inches in length.

6.5. **Parapet Walls.** Unless reinforced to withstand safely the earthquake and the wind loads to which they may be subjected, parapet walls shall be at least 8 inches thick and their height shall not exceed three times their thickness. (See Appendix 6.5.)

Section 7. Bond

7.1. **Walls of Solid Masonry Units.** Solid masonry bearing and nonbearing walls shall be bonded in accordance with Section 7.1.1, Bonding with Bonders or Section 7.1.2, Bonding with Metal Ties. (For grouted masonry walls, see Section 8.)

7.1.1. ***Bonding with Bonders (Headers).*** The facing and backing shall be bonded so that not less than 4 percent of the wall surface of each face is composed of bonders (headers) extending not less than 4 inches into the backing. The distance between adjacent full-length headers shall not exceed 24 inches either vertically or horizontally. In walls in which a single bonder does not extend through the wall, bonders from the opposite sides shall overlap at least 4 inches, or bonders from opposite sides shall be covered with another bonder course overlapping the bonder below at least 4 inches.

7.1.2. ***Bonding with Metal Ties.*** The facing and backing shall be bonded with corrosion-resistant metal ties conforming to the requirements of Section 7.6 for cavity walls. There shall be one metal tie for not more than each 4½ square feet of wall area. Ties

in alternate courses shall be staggered, the maximum vertical distance between ties shall not exceed 18 inches, and the maximum horizontal distance shall not exceed 36 inches. (See Appendix 7.1.2 for figure.) Walls so bonded shall conform to the allowable stress, lateral support, thickness (excluding cavity), height and mortar requirements for cavity walls.

7.2. **Masonry Walls of Hollow Units.** Where two or more hollow units are used to make up the thickness of a wall, the stretcher courses shall be bonded at vertical intervals not exceeding 34 inches by lapping at least 4 inches over the unit below, or by lapping at vertical intervals not exceeding 17 inches with units which are at least 50 percent greater in thickness than the units below; (see Appendix 7.2) or by bonding with corrosion-resistant metal ties conforming to the requirements of Section 7.6.1. There shall be one metal tie for not more than each 4½ square feet of wall area. Ties in alternate courses shall be staggered, the maximum vertical distance between ties shall not exceed 18 inches, and the maximum horizontal distance shall not exceed 36 inches. (See Appendix 7.1.2 for figure.) Walls bonded with metal ties shall conform to the requirements for allowable stress, lateral support, thickness (excluding cavity), height and mortar for cavity walls. Hollow masonry units shall have full mortar coverage of the ends and edges of the face shells in both the horizontal and vertical joints. (See Appendix 4.2.1.)

7.3. **Stone Walls.**

7.3.1 ***Ashlar Masonry.*** In ashlar masonry, bond stones uniformly distributed shall be provided to the extent of not less than 10 percent of the area of exposed faces.

7.3.2. ***Rubble Stone Masonry.*** Rubble stone masonry 24 inches or less in thickness shall have bond stones with a maximum spacing of 3 feet vertically and 3 feet horizontally, and if the masonry is of greater thickness than 24 inches, shall have 1 bond stone for each 6 square feet of wall surface on both sides.

7.4. **Openings in Walls of Plain Concrete.** Reinforcement symmetrically disposed in the thickness of the wall shall be placed not less than 1 inch above and 2 inches below openings and extend not less than 24 inches each side of such openings or be of equivalent developed length with hooks. The minimum reinforcement both above and below openings shall consist of the equivalent of one ⅝-inch round bar for each 6 inches in wall thickness.

7.5. **Faced Walls.**

7.5.1. ***Bonding Masonry Facing.*** The actual (not nominal) thickness of materials used for facing shall be not less than 2 inches and in no case less than ⅛ the height of the unit. Masonry facing shall be bonded to the backing as prescribed in Section 7.1, Walls of Solid Masonry Units.

7.5.2. ***Bonding Ashlar Facing.*** The percentage of bond stones for ashlar masonry shall be computed from the exposed face area of the wall. At least 10 percent of the face area shall consist of bond stones which extend 4 inches or more into the backing wall and are uniformly distributed. Every bonding stone, and, except when alternate courses are full bond courses, every stone not a bond stone, shall be securely anchored to the backing with substantial corrosion-resistant metal anchors with a cross-section of not less than 3/16-inch by

1 inch or its equivalent in cross-sectional area. There shall be at least 1 anchor to each stone and not less than 2 anchors for each stone more than 2 feet in length and 3 square feet in face area; facing stones of greater size shall have at least 1 anchor to each 4 square feet of the face area of the unit as applied but not less than two anchors.

7.6. **Hollow Walls (Cavity and Masonry Bonded).**

7.6.1. ***Cavity Walls.*** The facing and backing of cavity walls shall be bonded with $\frac{3}{16}$-inch diameter steel rods or metal ties of equivalent stiffness embedded in the horizontal joints. There shall be one metal tie for not more than each $4\frac{1}{2}$ square feet of wall area. Ties in alternate courses shall be staggered as indicated in Section 7.1.2 (see Appendix 7.1.2. for figure), the maximum vertical distance between ties shall not exceed 18 inches, and the maximum horizontal distance shall not exceed 36 inches. Rods bent to rectangular shape shall be used with hollow masonry units laid with the cells vertical; in other walls the ends of ties shall be bent to 90-degree angles to provide hooks not less than 2 inches long. Additional bonding ties shall be provided at all openings, spaced not more than 3 feet apart around the perimeter and within 12 inches of the opening. Ties shall be of corrosion-resistant metal, or shall be coated with a corrosion-resistant metal, or other approved protective coating.

7.6.2. ***Masonry-bonded Hollow Walls.*** Masonry bonded hollow walls shall be bonded as required in Section 7.1.1, Bonding with Bonders (Headers).

7.7. **Bonding of Intersecting Walls.**

7.7.1. ***Where Bonded.*** Masonry walls shall be securely anchored or bonded at points where they intersect and where they abut or adjoin the frame of a skeleton frame building. (See Section 11.1 for anchoring to floors.)

7.7.2. ***Bonding Bearing Walls.*** When two bearing walls meet or intersect and the courses are built up together, the intersections shall be bonded by laying in a true bond at least 50 percent of the units at the intersection.

7.7.3. ***Walls Carried Up Separately.*** When the courses of meeting or intersecting bearing walls are carried up separately, the intersecting walls shall be regularly toothed or blocked with 8-inch maximum offsets and the joints provided with metal anchors having a minimum section of $\frac{1}{4}$ inch by $1\frac{1}{2}$ inches with ends bent up at least 2 inches, or with cross pins to form anchorage. Such anchors shall be at least 2 feet long and the maximum spacing shall be 4 feet.

7.7.4. ***Bonding Nonbearing Walls.*** Meeting or intersecting nonbearing walls shall be bonded or anchored to each other in an approved manner.

SECTION 8. GROUTED MASONRY

8.1. **Materials.** Materials used in grouted masonry shall conform to the requirements of Section 2, Materials, provided that masonry units in either the facing or backing, but not necessarily both, at the time of laying, shall absorb in 24 hours of cold immersion an amount of water weighing at least five percent of the dry weight of the unit.

8.2. **Construction.** All masonry units in the outer wythes shall be laid with full head and bed joints of Type A-1 or A-2 mortar and al

interior joints shall be filled with grout. Masonry units in the interior wythes shall be placed or floated in grout poured between the two outer wythes. One of the outer wythes may be carried up not more than three courses before grouting but the other shall be carried up not more than one course above the grout. Each pour of grout shall be stopped at least 1½ inches below the top and properly stirred. The grouted longitudinal vertical joints shall be not less than three-fourths inch wide. Bonders shall not be used.

SECTION 9. VENEERS

9.1. **Requirements.** Installation of veneers shall be in conformance with generally accepted good practice.[3]

9.2. **Load.** Veneers shall not be considered as part of the wall in computing the strength of bearing walls nor shall they be considered a part of the required thickness of walls.

SECTION 10. GLASS BLOCK

10.1. **Where Permitted.** Masonry of glass blocks may be used in nonload-bearing exterior or interior walls and in openings which might otherwise be filled with windows, either isolated or in continuous bands, provided the glass block panels have a thickness of not less than 3½ inches at the mortar joint and the mortared surfaces of the blocks are satisfactorily treated for mortar bonding.

10.2. **Size of Panels.** Glass block panels for exterior walls shall not exceed 144 square feet of unsupported wall surface nor 25 feet in length nor 20 feet in height between supports. For interior walls, glass block panels shall not exceed 250 square feet of unsupported area nor 25 feet in one direction between supports.

10.3. **Reinforcement of Exterior Panels.**

10.3.1. ***Anchorage.*** Exterior glass block panels shall be held in place in the wall opening to resist both external and internal pressures due to wind. Panels shall be set in recesses at the jambs and, for panels exceeding 10 feet in horizontal dimension between supports, at the head as well, so as to provide a bearing surface at least one inch wide along the panel edges; except that when approved by the building official for panels exceeding neither 100 square feet in area nor 10 feet in either horizontal or vertical dimension, and situated 4 stories or less, and less than 52 feet above grade level, anchorage may be provided by means of noncorrodible perforated metal strips.

10.3.2. ***Placing Reinforcement.*** Glass block panels shall have reinforcement in the horizontal mortar joints, extending from end to end of mortar joints but not across expansion joints, with any unavoidable joints spliced by lapping the reinforcement not less than 6 inches. The reinforcement shall be spaced not more than two feet apart vertically. In addition reinforcements shall be placed in the joint immediately below and above any openings within a panel. The reinforcement shall consist of two parallel longitudinal galvanized steel wires, No. 9 gauge or larger, spaced 2 inches apart, and having welded thereto No. 14 or heavier gauge cross wires at intervals not exceeding 8 inches, or the equivalent approved by the building official.

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[3] A proposed standard for the installation of veneers is under preparation, and will be submitted to Sectional Committee A41 for consideration as a separate standard.

10.4. **Mortar.** Glass block shall be laid in Type A–1, A–2, or B mortar. Both vertical and horizontal mortar joints shall be at least ¼ and not more than ⅜ inch thick and shall be completely filled.
10.5. **Expansion Joints.** Every exterior glass block panel shall be provided with expansion joints at the sides and top. Expansion joints shall be entirely free of mortar, and shall be filled with resilient material.

Section 11. Miscellaneous Masonry Requirements

11.1. **Anchoring of Walls.**

11.1.1. ***Meeting or Intersecting Walls.*** Masonry walls that meet or intersect floors or columns shall be securely bonded or anchored if these are depended upon for lateral support of the walls. (See Section 7.7, Bonding of Intersecting Walls.)

11.1.2. ***Fastening Joists or Beams.*** The ends of floor joists or beams bearing on masonry walls shall be securely fastened to the walls in an approved manner. (See Appendix 11.1.2.)

11.1.3. ***Spacing.*** When lateral support for walls is to be provided by anchorage to floor or roof joists which are parallel to the walls, the anchors shall be spaced at intervals not exceeding 6 feet and shall engage not less than three joists; these joists shall be bridged solidly at the anchors. (See Appendix 11.1.3.)

11.1.4. ***Anchoring Structural Members.*** Structural members including roof members, framing into or supported by walls or piers shall be adequately anchored. (See Appendix 11.1.4.)

11.2. **Chases and Recesses.**

11.2.1. ***Limitations.*** Except as provided in Section 11.2.1.1, chases and recesses in masonry walls shall not be deeper than ⅓ the wall thickness nor longer than 4 feet horizontally or in horizontal projection, and shall have at least 8 inches of masonry in back of the chases and recesses and between adjacent chases or recesses and the jambs of openings. Chases and recesses shall not be cut in walls of hollow masonry units or in hollow walls, but when permitted may be built in. There shall be no chases or recesses within the required area of a pier. The aggregate area of recesses and chases in any wall shall not exceed ¼ of the whole area of the face of the wall in any story.

11.2.1.1. Exceptions for 8-Inch Walls. In residence buildings not over 2 stories in height, vertical chases not more than 4 inches deep and not more than 4 square feet of wall area may be built in 8-inch walls, except that recesses below windows may extend from floor to sill and be the width of the opening above. Masonry directly above chases or recesses wider than 12 inches shall be supported on lintels.

11.2.2. ***Recesses for Stairways or Elevators.*** Recesses for stairways or elevators may be left in walls, but in no case shall the walls at such points be reduced to less than 12 inches unless reinforced by additional piers, or by columns or girders of steel, reinforced masonry, or concrete, securely anchored to the walls on each side of such recesses. Recesses for alcoves and similar purposes shall have not less than 8 inches of material at the back. Such recesses shall be not more than 8 feet in width and shall be arched over or spanned with lintels.

11.3. **Lintels and Arches.**

11.3.1. ***Material.*** The masonry above openings shall be supported by arches or lintels of metal or reinforced masonry which shall bear on the wall at each end for not less than 4 inches. Stone or other nonreinforced masonry lintels shall not be used unless supplemented on the inside of the wall with iron or steel lintels or with suitable masonry arches or reinforced masonry lintels carrying the masonry backing.

11.3.2. ***Stiffness.*** Steel or reinforced masonry lintels shall be of sufficient stiffness to carry the superimposed load without deflection of more than $1/360$ of the clear span.

11.3.3. ***Design.*** Masonry arches shall be designed in accordance with good engineering practice.

11.4. **Beams and Joist Supports.**

11.4.1. ***Beams.*** Beams, girders, or other concentrated loads supported by a wall or pier, shall have bearing at least 3 inches in actual length upon solid masonry not less than 4 inches in depth or on a metal bearing plate of adequate design and dimensions, or other provision shall be made to distribute safely the loads on the wall or pier.

11.4.2. ***Joists.*** Joists shall have bearing at least 3 inches in actual length upon solid masonry at least 2¼ inches in depth, or other provision shall be made to distribute safely the loads on the wall or pier.

11.4.3. ***Support on Wood.*** Unless specifically approved by the building official, no masonry shall be supported on wood girders or other form of wood construction.

11.5. **Corbelling.**

11.5.1. ***Maximum Projection.*** Except for chimneys, the maximum corbelled horizontal projection beyond the face of the wall shall be not more than ½ the wall thickness and the maximum projection of one unit shall neither exceed ½ the depth of the unit nor ⅓ its width at right angles to the face which is offset.

11.5.2. ***Corbelling Chimneys.*** No chimney shall be corbelled from a wall more than 6 inches nor shall a chimney be corbelled from a wall which is less than 12 inches in thickness, unless it projects equally on each side of the wall, provided that in the second story of two-story dwellings, corbelling of chimneys on the exterior of the enclosing walls may equal the wall thickness. In every case the corbelling shall not exceed 1 inch projection for each course of brick projected.

11.6. **Cornices.** The centers of gravity of stone cornices shall be inside of the outer wall face. Terra cotta cornices and metal cornices shall be structurally supported.

11.7. **Drainage of Hollow Walls.** In cavity walls the cavity shall be kept clear of mortar droppings during construction. Approved flashings shall be installed in hollow walls and adequate drainage provided to keep dampness away from the backing. (See Appendix 11.7.)

11.8. **Use of Existing Walls.**

11.8.1. ***Permission Required.*** An existing masonry wall may be used in the alteration or extension of a building provided that under the new conditions it meets the requirements of this standard and is structurally sound or can be made so by reasonable repairs.

No existing wall shall be used for the alteration or extension of building, or increased in height without specific written permissio from the building official.

11.8.2. ***Walls of Insufficient Thickness.*** Existing masonr walls which are structurally sound but which are of insufficient thick ness when increased in height shall be strengthened by an additio of the same material not less than 8 inches in thickness laid in Typ A–1 mortar. The foundations and lateral support shall be equiva lent to those elsewhere required for newly constructed walls unde similar conditions. All reinforcing linings shall be thoroughly bonde into existing masonry by toothings to assure combined action of wa and lining. Such toothings shall be distributed uniformly throughou the wall and shall aggregate in vertical cross-sectional area not les than 15 percent of the total vertical area of the lining. Stresses i the masonry under the new conditions shall not exceed the allowabl stresses prescribed in Section 4.2.2, Composite Walls. (See Appen dix 11.8.2.)

11.9. **Precautions During Erection.**

11.9.1. ***Bracing to Resist Lateral Loads.*** Masonry walls i locations where they may be exposed to high winds during erectio shall not be built higher than 10 times their thickness unless ade quately braced or until provision is made for the prompt installatio of permanent bracing at the floor or roof level immediately above th story under construction. Back fill shall not be placed agains foundation walls until they have been braced to withstand the hor zontal pressure. (See Appendix 11.9.1.)

11.9.2. ***Wetting of Brick.*** Brick (clay or shale) shall be wette when laid unless their gain in weight resulting from partial immersio flatwise in ⅛ inch of water for 1 minute is less then ¾ ounce per 3 square inches of immersed area. (See Appendix 11.9.2.)

11.9.3. ***Protection Against Freezing.*** Masonry shall be pro tected against freezing for at least 48 hours after being laid. Unles adequate precautions against freezing are taken, no masonry shall b built when the temperature is below 32 F. on a rising temperature, o below 40 F. on a falling temperature, at the point where the work i in progress. No frozen materials shall be built upon. (See Appendi 11.9.3.)

Appendix

The Appendix consists of explanatory matter referring to variou parts of the recommended code requirements. It is not a part of th American Standard Building Code Requirements for Masonry bu is presented as background material for users of the standard. A certain amount of material describing "good practice" is include The subdivisions of the Appendix are numbered to correspond wit the section numbers of the standard.

1.3. **Dimensions.** For information on modular dimensions se American Standard A62.1–1945, Coordination of Dimensions o Building Materials and Equipment [1],[4] and A62.2–1946, Sizes o Clay and Concrete Modular Masonry Units of the American Stand ards Association [2].

The intent of Section 1.3 is to avoid unnecessary repetition of th adjective "nominal" before each nominal dimensional requirement i

[4] Figures in brackets indicate the literature references on page 37.

the standard. If the dimension is not nominal, the adjective "actual" is used. At the present time (1953) the thickness of mortar joints is considered to be not exceeding ½ inch when used with structural clay products, not exceeding ⅜ inch for concrete block and ¼ or ⅜ inch for glass block. The dimensions for concrete as specified in the standard are usually actual in practice, but when used with masonry units, as in foundations supporting masonry, or in spandrels combining concrete and masonry, the dimensions should be considered as nominal, with the difference between "nominal" and "actual" corresponding to the thickness of the mortar joint used with the unit under consideration.

1.4. **Alternate Materials and Constructions.** Procedures for approving new constructions having merit should be as simple as possible so that use of such constructions, when justified by available information or by readily ascertaininable facts, will not be retarded unduly. If records of service performance covering a period of several years, or the results of laboratory or field tests that either are similarly time-consuming or of prohibitive cost, are required as proof of acceptability, the development and utilization of improved or less costly materials and methods will be discouraged. On the other hand, perfunctory or otherwise inadequate investigations and requirements relating to novel constructions may lead to unsafe structures.

It appears to be the consensus of experts that the desired objectives will not be attained by insisting that all new construction proposed for use be subjected to precisely the same kind of examinations and tests and be required to conform to the same limitations. In many instances, opinions of structural and materials engineers may be of more value in estimating the durability and other essential properties of an untried construction than the results of simple routine tests. Accordingly, detailed directions for investigating the adequacy of new constructions are not given, nor are all pertinent properties listed. A definite size of wall panels for structural tests and methods for conducting these tests are recommended in the belief that standardization of these features will be of assistance in interpreting the results and will tend to minimize the need of making separate tests in each of many different localities.

It is necessary to guard against unqualified acceptance of data on strength of masonry built from unusual shapes or combinations of units unless satisfactory evidence is made available concerning the identity or relation between the workmanship used on the specimen submitted and workmanship that may be reasonably expected in commercial construction. If the bed joints in masonry specimens submitted for test had been leveled or if coverage of hollow units includes webs and longitudinal shells, either new test specimens should be constructed according to prevailing methods or the factor of safety should be increased beyond the 4 given as a minimum in Section 1.5.3. A suggested procedure is to consider that the strength of masonry built with commercial workmanship is proportional to the ratio of the area given a firm bearing by the mortar to the gross area, and to discount accordingly the values determined on masonry built with "superior workmanship" such as described in BMS 5 [3].

Suitable methods of testing masonry walls for strength are described in ASTM E 72–51 T, Tentative Methods of Conducting Strength Tests of Panels for Building Construction [4].

1.5.1. **Tests—When Required.** In other sections of the standard, requirements are set forth covering the quality of materials to be used in buildings. The purpose of Section 1.5.1 is to give the building official authority to require tests of materials and constructions when there is doubt of their quality or their conformity to the intent of the standard. Under the provisions of this section the building official may require tests to be repeated if at any time there is reason to believe that a material or construction no longer conforms to the requirements on which its approval was based. For the most part the specifications for materials referred to in the standard include standard methods of testing or refer to standard methods. The building official should insist on strict adherence to these standard methods in all official tests.

Differences in the color and structure of masonry units should not be considered a sufficient basis alone for rejection since such differences may be caused by differences in the chemical composition of the raw materials from which the units are made and may have no relation to the strength, durability or other significant physical properties of the units.

2. **Materials—Reference to Standards.** Modern, well-written building codes are characterized by a liberal use of nationally recognized standards. Through their use the code writer benefits from the work of committees of national organizations having much better facilities for gathering and evaluating data than local committees can be expected to possess. Moreover, the use of nationally recognized standards tends toward greater uniformity in codes throughout the country, an important consideration to designers, builders, and producers of material who do work in more than one locality.

Although there are several methods of utilizing nationally recognized standards, a specific method of adoption by reference has been employed in this standard. The standard is referred to by title, serial, designation, year of adoption, and the name of the sponsor organization is given. Some critics of earlier drafts of the A41 standard favored a more general reference to national standards by stating that the standard "as amended from time to time" should apply. The expedient is not regarded favorably by many authorities on the subject, however, because of the possibility that the courts will refuse to uphold an ordinance utilizing such a method of reference on the ground of uncertainty as to what edition of the standard is meant, and as an improper delegation of legislative authority. While this procedure might be suitable for an ASA standard that would be used only as a reference document, the possibility that the ASA standard might be copied verbatim into a local code has also to be considered. For a discussion of the use of standards, see NBS Building Materials and Structures Report BMS116, Preparation and Revision of Building Codes [5] by George N. Thompson, National Bureau of Standards.

Constitutional provisions affecting the adoption of standards by reference vary in different States and legal opinion is somewhat divided on the question. Hence, it would be well for code writers to consult the appropriate law officer before adopting any method of utilizing recognized standards, and to ascertain whether the procedure has legal sanction in order to avoid possible later attack on the method employed.

2.1.1. **Second-Hand Materials.** Irrespective of the original grading of masonry units, compliance with code requirements of material which has been exposed to weather for a term of years cannot be assumed in the absence of test. Much salvaged brick comes from the demolition of old buildings constructed of solid brick masonry in which hard-burned bricks were used on the exterior and salmon brick as back-up, and, since the color differences which guided the original brick masons in their sorting and selecting of bricks become obscured with exposure and contact with mortar, there is a definite danger that these salmon bricks may be used for exterior exposure with consequent rapid and excessive disintegration. Before permitting their use, the building official should satisfy himself that second-hand materials are suitable for the proposed location and conditions of use. The use of masonry units salvaged from chimneys in not recommended, since such units may be impregnated with oils or tarry material.

2.2.1. **Building Brick.**

ASTM Specifications for Building Brick (Solid Masonry Units Made from Clay or Shale), C 62–50, provides essentially a classification for durability. The classification by strength given in Section 2 of this specification is the one used in this standard.

From the standpoint of durability the grades of ASTM Specifications for Sand-Lime Brick, C 73–51, are equivalent to the corresponding grades of ASTM C 62–50. Sand-lime brick differ from brick made from clay and shale in that the compressive and transverse strengths of sand-lime brick are much better correlated with the results of durability tests than are the same properties of brick made from clay and shale. Like certain concrete units, high-strength sand-lime brick tend to gain strength during laboratory cycles of freezing and thawing [6].

Few, if any, data have been obtained on the durability of concrete bricks tested as bricks. The results of numerous tests on mortars and concretes warrant the conclusion, however, that the requirement for the grade A brick of ASTM C 55–52 will reasonably insure durability where exposures correspond to those considered in this standard. ASTM C 55–52 does not provide a minimum age for test. It may be assumed, however, that the physical requirements specified apply to material "at the time of delivery." The objection to the use of concrete bricks at early ages is based upon the observed tendency for excessive shrinkage rather than upon low strength. Steam curing under pressure is considered to be advantageous both from the standpoint of decreasing subsequent shrinkage and increasing early strength. See discussion of concrete masonry units. (See Appendix 2.2.3.)

Since temperature must drop below 32 F for freezing to occur, it follows that in those sections of the United States where temperatures seldom fall below freezing, the degree of durability called for by grade MW of ASTM C 62–50 and ASTM C 73–51 and grade A of C 55–52 is unnecessary for walls above grade. Those portions of the South Atlantic States excluding mountainous areas, the Gulf States, and the Pacific coastal region would not require compliance with grade MW as far as resistance to frost action is concerned.

Laboratory experiments also indicate that the effect of freezing and thawing cycles in producing disintegration is related to the degree of saturation of the test specimen while being frozen [7]. The nearer the

water content of a porous body approaches complete saturation (all pores completely filled), the greater the tendency to fail when frozen. High saturations result from continuous contact with or immersion in water or intermittent wetting under conditions such that moisture does not escape from the unit. Masonry may become highly saturated if it is in contact with water-bearing soil, as in a retaining wall or foundation, or is in parapet walls poorly protected on their upper surface and is sealed by a through flashing and an impermeable coating, such as oil paint or bitumen, on one or both of the vertical surfaces. Numerous instances have been noted where disintegration of the inside face of a parapet followed sealing.

When water is in contact with a surface of a dry unit, water tends to enter the unit by capillarity. If there is enough water and the time of contact is sufficiently long, the water will strike through from face to face, giving a degree of saturation equaling or exceeding that resulting from a 24-hour submersion in water at room temperature. This wetting through from face to face describes the condition of being "permeated" referred to in ASTM C 62–50. In the absence of defective workmanship, masonry protected from above by flashing and with only one vertical surface exposed is unlikely to be permeated with water by ordinary weather. An additional degree of safety results from the probability that freezing weather will only occasionally follow a heavy and long continued rain without some intermediate drying. In general, units with high rates of absorption have correspondingly rapid rates of drying. The probability of permeation is obviously affected by the amount and nature of precipitation. Precipitation as snow would not introduce water into vertical surfaces. ASTM C 62–50 takes account of this probability by suggesting the use of grade NW bricks for exterior exposure where the average annual precipitation is less than 20 inches. Disregarding snow as precipitation, that portion of the United States west of a north and south line through the center of Kansas can in general be considered as having an annual precipitation of less than 20 inches.

2.2.3. **Concrete Masonry Units.** Concrete block and concrete brick are subject to shrinkage upon drying. The amount of this shrinkage in masonry is a function of the moisture loss from the units after the time of laying and also varies with the nature of the aggregate and method of curing. To minimize shrinkage of walls the units must be sufficiently dry when laid. Such a condition of units may be obtained by drying until the desirable moisture condition is attained. High pressure steam curing in autoclaves is helpful in producing units of relatively low moisture content and low shrinkage and moisture volume change properties [8, 9]. In either case the units must be properly protected from moisture gain on the job.

2.2.4.2. **Natural Stone.** With respect to stone, the term "durability" should be understood to include resistance to all weathering agents to which the stone is exposed, and in cases of steps, floors, etc., resistance to abrasion. Weathering agents of most concern are heat, cold, moisture, and atmospheric gases. The question of durability for a given stone can usually be settled by examining structures showing the stone under use similar to those proposed. For such studies the stone producer or local stonesetter should be called upon for a list of structures. Untried stones under consideration for

important structures should not be used before thorough testing in the laboratory.

2.3.2. **Plain Concrete.** The best general measure of the resistance of concrete to freezing and thawing and to weathering is the quality of the cement paste as determined by the proportion of water to cement. However, for a given water-cement content the resistance is materially increased by air entrainment. Maximum water contents specified give good resistance with normal concrete and all types of sound aggregate. Higher water content can be used with air entrainment, under some climatic conditions, or with some aggregates. Where satisfactory results with greater water content can be shown by tests or experience, such concrete should be permitted. Since allowable stresses are given as a function of the compressive strength of the concrete, the factor of safety remains the same regardless of the strength of the concrete and only nominal minimum strength requirements are necessary. This permits the safe use of relatively weak lightweight concrete where the strength is not as important as other properties such as insulation.

3.1. **Quality of Mortar.** The 1944 edition of this standard presented an abbreviated specification for mortar and described in the appendix (2–14) the theory and application of the "flow after suction" test. The present standard substitutes for this material reference to ASTM Tentative Specifications for Mortar for Unit Masonry (C 270–52 T).[5] This specification follows rather closely in content the one outlined in the 1944 edition. Among the changes are the insertion of a new grade of mortar (A–2) between the original A (now A–1) and B grades. In the "proportion requirements" a mortar proportioned 1:1:6 portland cement-Type II masonry cement-sand by volume is considered equivalent in strength to one 1:1/4:3 portland cement-lime-sand by volume, and the Type A–2 mortar as either 1:2:9 portland cement-Type II masonry cement-sand or a 1:1/2:4–1/2 portland cement-lime-sand mixture by volume. The "property requirements" specify that an A–2 mortar have a strength of not less than 1800 psi at 28 days. The minimum strengths for Type B and Type C mortars have been raised from 600 to 750 psi and from 200 to 350 psi respectively. The original low values in A41.1–1944 had been set so that all cement-lime mortars of a particular specified composition could be expected to pass the requirements for compressive strength given for that composition. It was found in practice that special methods of cure were used which gave higher strengths for Type C so that mortars of this composition qualified and were used as Type B mortars. Since C 270–52 T now specifies "damp closet" curing for Type B and Type C mortars instead of curing in water as specified in the earlier edition, increase in required strength for these mortars may be regarded as taking account of a change in test method rather than as an upgrading in strength. The 1:1:6 mortars used in the wall specimens whose tests supplied the data upon which the allowable compressive stresses for solid brick masonry were based, averaged over 1,000 psi. These mortar specimens were cast at "mason's consistency" as 2 by 4-inch cylinders and were cured in water [10].

[5] The substitution of Type II Masonry Cement for Type I Masonry Cement in "C" mortar as given in Table II on page 385 of Part 3 of the 1952 Book of Standards is believed to be an inadvertence. It is expected that this will be corrected in a forthcoming revision of C 270–52 T.

For the convenience of the reader, the requirements for mortar given in ASTM Tentative Specifications for Mortar for Unit Masonry (C 270–52 T) are given in table 1.

TABLE 1. *Mortar requirements*

Mortar type	Parts by volume				Minimum average compressive strength of three 2-in. cubes at 28 days
	Portland cement	Masonry cement	Hydrated lime or lime putty	Aggregate measured in damp, loose condition	
					psi
A–1	1	1 (type II)		Not less than $2\frac{1}{4}$ and not more than 3 times the sum of the volumes of the cements and lime used.	2,500
	1		$\frac{1}{4}$		
A–2	$\frac{1}{2}$	1 (type II)			1,800
	1		Over $\frac{1}{4}$ to $\frac{1}{2}$		
B		1 (type II)			750
	1		Over $\frac{1}{2}$ to $1\frac{1}{4}$		
C		1 (type I or type II) [a]			350
	1		Over $1\frac{1}{4}$ to $2\frac{1}{2}$		
D	1		Over $2\frac{1}{2}$ to 4		75

[a] The correction referred to in footnote 5 is made in the above tabulation.

Mortars meeting the proportion requirements in table 1 and composed of ingredients conforming to the applicable ASTM specifications are assumed to meet the compressive strength requirements listed in the last column and to have water retentions of not less than 70 percent when mixed to an initial flow of 100 to 115. The selection of mortars can be made either by specifying ingredients and proportions or by specifying compressive strength and water retentivity.

Specification C 270–52 T in its present form provides little protection against unsound (expanding) mortar. Although Portland Cement (C 150–49) and Natural Cement (C 10–49 T) must meet a 0.50 percent limit on autoclave expansion, the specifications for Masonry Cement (C 91–51) [6] and Hydraulic Hydrated Lime (C 141–42) provide only "pat tests" for soundness. The Specification for Hydrated Lime for Structural Purposes (C 207–49) covers both "Special" and "Normal" hydrates. A dolomitic "normal" hydrate usually contains a considerable quantity of unhydrated magnesium oxide which may cause damaging expansion upon conversion to magnesium hydroxide in a hardened mortar [11]. "S" (special lime) which includes both high-calcium hydrate and autoclaved dolomitic hydrate has negligible expansion. Masonry cement containing excessive unhydrated magnesium oxide or made from portland cement clinker not passing the soundness test prescribed in C 150–49 may also cause expansion in mortar.

3.4. **Types of Mortar Permitted.** The selection of mortars permitted for the several kinds of masonry listed in the table is, for the

[6] A tentative revision of this specification was approved in 1953 to provide a 1.0 limit on autoclave expansions on specimens tested at age of 7 days. See page 4 of the 1953 Preprint of the Report of ASTM Committee C–1 on Cement.

purposes of this standard, based upon compressive strength. It should not be assumed that higher strength mortars are preferable to lower strength mortars where lower strength mortars are permitted for particular uses. See, for example, appendix material on Workmanship, Section 4.2.1.

The recognition of Type D mortar in the standard has been questioned. The objections to the use of low strength mortars such as Type D, are based upon the record of behavior of masonry laid with such mortars when subjected to lateral forces as in earthquakes, its poor resistance to weathering when exposed to freezing in the presence of moisture and its deficiency in hydraulicity (hardening in the presence of moisture). In consideration of the redefinition of Type D mortar as a mixture of portland cement and lime (1:4:15 by volume) instead of the straight lime mortar (1:3) as used in the 1944 edition of the standard, its use is continued although subject to considerable restriction as heretofore.

There is evidence indicating that mortar in walls other than parapets or foundations is not ordinarily subject to severe weathering even though the prevailing climate provides high precipitation and freezing temperatures. The requirements for wall thickness and lateral support where Type D mortar is permitted, are considered to provide safety except in structures designed to withstand high lateral forces such as from earthquakes.

4.2 **Allowable Stresses.** Except for the interpolation of compressive stresses for masonry laid with Type A–2 mortar, the figures for brick and stone masonry remain unchanged from the 1944 edition of the standard. In the absence of comparable data on the strength of masonry laid with A–2 mortar, the arithmetical means of the A–1 and B values are used.

The stresses for brick masonry in the 1944 edition of the standard were copied from the 1931 "Modifications in recommended minimum requirements for masonry wall construction of the Building Code Committee of the Department of Commerce" [12] and values for stresses for brick laid with C mortar were interpolated. These stresses were based upon data provided by the National Bureau of Standards [10] compared with earlier values (Compressive Tests on Brick Masonry—A compilation of data covering 708 individual tests of brick masonry in the form of piers and walls, prepared by the Building Code Committee of the U. S. Department of Commerce). These studies showed the importance of workmanship as a factor in the compressive strength of masonry. In the 1931 modifications an attempt was made to take account of this factor by the provision "that where the masonry is laid with smooth level horizontal joints and completely filled vertical joints and is thoroughly inspected and where the effects of eccentric and concentrated loads and lateral forces are fully analyzed and allowance made for them, the working stresses in this table may be increased by 50 percent." This allowance was omitted in A41.1–1944 because it was found that "smooth level horizontal joints" were practically unobtainable under field conditions (See Appendix 4.2.1 on Workmanship) and furthermore, that certain code authorities and designers were assuming that the workmanship described above was standard.

The selection of allowable stresses for brick masonry for the 1931 modifications was based essentially on the following considerations. All available data on strengths were reviewed and classified according

to gradings of brick strength and mortar strength. A wide scatter of strength was found within these grades even when brick strengths and mortar types did not significantly differ. After elimination of scattered low strengths which appeared to result from faulty test methods or the use of nonstandard material, insofar as could be determined from study of the original reports, values were set such that masonry made of brick and mortar within the classification limits considered, could be expected to exceed the established minimum strength for 95 percent of the tests. Consideration was given to the relation between loads at first crack and ultimate loads where data were available. The following values were established and accepted by the Department of Commerce Building Code Committee:

Brick grading	Assumed compressive strengths with cement-lime-sand mortars		
	1C:1/4L:3S	1C:1L:6S	1L:3S
psi	*psi*	*psi*	*psi*
8,000 plus	2, 000	1, 200	800
4,500 to 8,000	1, 000	800	400
2,500 to 4,500	700	560	275
1,500 to 2,500	500	250	150

The allowable stresses were established by applying factors of safety of from 3 to 5 to the above values. The lower factors of safety were used where low strengths had resulted from the use of brick and mortar of low strength. In general, the higher the strength, the greater the variability.

The data on strength of masonry built of structural clay tile and concrete masonry units were reviewed and working stresses in compression have been selected so that the minimum safety factor with concentric loading is about 3½ [3, 13, 14, 15, 16].

The values for grouted solid masonry follow those of the Pacific Coast Building Officials Conference except that values are given for the use of "B" mortar [17]. Relatively low limits are placed on the allowable compressive stresses on the gross areas of cavity walls, since loading is usually on the inner wythe only.

The working stresses for stone masonry are traditional. The values given are from the 1909 Edition of Baker's "Masonry Construction" and represent the estimated loads on a number of existing stone structures, for the most part bridge piers.

Proposals for allowable stresses for shear and for tension in extreme fiber in flexure in unit masonry have been considered by the Committee. But until agreement can be reached as to appropriate values for allowable tensile stresses under various conditions, it is considered prudent to neglect the tensile resistance of non-reinforced masonry. The usefulness to designers of an assumed strength in tension is well understood. The disagreement is over the basis of estimating tensile strength in the absence of tests and assigning a reasonable value. For concrete there is a fairly uniform relation between compressive strength and tensile strength. The 3 percent allowance for tensile stress in flexure (Section 4.2.3) represents a factor

of safety of about five. No such relation can be said to hold for unit masonry. Except for very low strength mortars, failure in tension usually takes place at the interface between the mortar and the unit. Numerous tests on two-brick assemblages have shown that strength in tension depends upon a number of factors. There is general agreement that the "initial rate of absorption" (suction) of the unit is very important [18]. Flowability of the mortar is at least equally important; very weak and incomplete bond is obtained with mortars having insufficient mixing water [19, 20]. Among other factors are "water retentivity" and strength of the mortar, extent of bond and the nature of the surface of the unit in contact with the mortar. Delay in placing units on an already spread bed of mortar and moving the unit after it has been laid in place are known to lower or completely destroy bond. Curing with the joint under load increases bond strength [21]. Most of the data on the transverse strength of solid masonry walls (4 to 6 ft long and from 8 to 12 ft high) are summarized in "Brick and Tile Engineering" [22] by H. C. Plummer. These data do not, however, permit evaluation of the relative effect of "superior workmanship", rate of absorption of the bricks, and strength of mortar. With 4 exceptions, all of the 50 walls were laid with "superior workmanship" which, as far as defined, included complete filling of all joints and leveled bed joints. (See BMS5 [3] for description of workmanship.) All reported data are on specimens built and cured in the laboratory.

Obviously the probability that masonry may crack in service must be considered. Among the commonly accepted and familiar causes of cracks are "foundation settlement, deflection of beams, overloading, expansion and contraction with temperature change, and various features of faulty design and construction." In addition, cracking of structures has been ascribed to shrinkage of concrete masonry units, expansion of mortar either from unsound ingredients [11], or from reactions of the cementitious material with sulfates and the "moisture expansion" of certain clay products. "Moisture expansion" was demonstrated by Schurecht [23, 24] on architectural terra cotta. The same reaction has been noted on a few structural clay tile. The possibility of unsoundness as indicated by volume change exists for almost all of the materials used in masonry. The history of research in this field presents numerous illustrations of the discovery of hitherto unknown and unsuspected behavior of materials resulting from unusual combinations of factors. The "alkali-aggregate" reaction is an example [25]. Troubles resulting from lapses in manufacturing control or the accidental inclusions of unsound ingredients are rare but are always possible. In the present state of materials specifications, the safeguards against some of these causes for volume change are inadequate or nonexistent. This, plus the quality of control of masons' techniques in practice, would indicate the desirability of using reinforced masonry where lateral stability is required beyond what is provided by the present standard.

4.2.1. **Higher Stresses.—Effect of Workmanship on Properties of Masonry.** From a comparison of the compressive strengths of brick walls, alike with respect to bricks and mortar but differing in the techniques used by the masons, the following conclusion was drawn [26]: Workmanship characterized by filled head (vertical or cross) joints and completely filled and leveled (unfurrowed) horizontal bed

joints gave an increase in compressive strength over the results of workmanship characterized by unfilled head joints and deeply furrowed bed joints of from 24 to 112 percent.

The commercial practicability of laying brick on completely filled and leveled bed joints was investigated with the help of a Washington, D. C. mason contractor. This contractor's practice was to guarantee compliance with and use of a specified quality of workmanship. His original specification was written around the description of the "A" workmanship given in Building Materials and Structures Report BMS7 [27] and his service included continuous supervision of the masons by qualified inspectors. The contractor reported after some months that brick masonry could not be commercially laid without some degree of furrowing of the bed joint. Tapping bricks down to line was difficult and adjustment of thickness of the mortar bed took time with resultant stiffening of the mortar. Since further study (BMS82) [28] had demonstrated that "there was no significant difference in the permeability of brick walls in which mortar for the bed joints was leveled or furrowed before placing the bricks, sufficient mortar having been used to cover the bricks," and the commercial impracticability of requiring leveled bed joints had been demonstrated, the "A" workmanship described in BMS82 is recommended as a standard of good workmanship in place of the "A" workmanship described in RP108 and BMS7.

The compressive strength of masonry of block or tile depends importantly upon the completeness with which the units are bedded. For end-construction masonry, the bedding has ranged from covering the two face shells only, to complete coverage of the ends of all shells and webs. The effect of quality of workmanship on the compressive strength of tile masonry is well illustrated by available test data. For example, NBS Technologic Paper 311 [14] reports the results of tests of some end construction walls for which the mason had bedded the longitudinal shells of the tiles but made no attempt to obtain mortar bearings for the webs or the transverse shells, and of other walls for which mortar bearings were provided for all shells and webs. References [3, 15, 16, 29] give some data on the compressive and transverse strength of walls built with concrete block. Mortar bedding for test walls of side construction tile has ranged from complete coverage of the bearing shells to only a strip of mortar about 1½ inches wide along the faces of the walls. Mortar was provided on the ends of the shells in both faces of the walls for the vertical joints.

The data that have been reported on strength of masonry under transverse loading (see Appendix 4.2) do not permit an evaluation of workmanship. If it be granted that failure in tension usually takes place at the interface between the unit and the mortar, it is evident that tensile strength is a function not only of adhesion but also of area bonding (degree of completeness of filling of the joints).

Requirements for minimizing the entrance of water into masonry (prevention of wet walls) have not been found in any of the building codes so far examined. Although dampness in a structure is generally recognized as bad from the standpoint of comfort and health and there is evidence that the durability of masonry is seriously affected by freezing and thawing and by leaching and crystallization of salts if much moisture is present [30, 31], the subject is not included in

codes possibly on account of uncertainty as to the legal status and enforceability of such provisions. The building official, however, is sometimes blamed for leaking masonry on the theory that such conditions are the fault of lax inspection. The following discussion of the factors concerned with building leak-proof masonry is presented for information.

(1) The rate of absorption [28, 32, 33, 34] of brick is very important. Either bricks should be selected having a rate of absorption (grams of water absorbed in 1 minute by 30 sq in. of brick surface when set in ⅛ in. depth of water) of under 20 g when dry (some authorities recommend 10 g) [28], or the rate of absorption of the brick should be lowered to this figure by wetting before laying.

(2) The mortar should be easily workable (plastic) and have a high water-retaining capacity. These two properties usually are associated. Harsh working mortars will usually both "bleed" (permit separation of water from the mortar) when used with impervious units and quickly stiffen when laid in contact with porous units. The flow after suction (measure of water retentivity) should not be less than 70 percent. For cement-lime mortar, the lime should be as plastic as is obtainable. Type "S" lime of ASTM C 207–49 (Hydrated Lime for Masonry Purposes), Special Finishing Hydrated Lime (ASTM C 206–49) and a high-calcium lime putty sufficiently aged so that it will meet the plasticity requirement given for "S" lime in C 207–49, have the desired properties. Masonry cements meeting the requirements of ASTM C 91–52T would be of satisfactory workability. All mortar should be mixed and kept tempered so that it will contain as much water as it can carry. The workability of the mortar should be satisfactory to the mason.

(3) To obtain brickwork impermeable to water, all bed and head joints in both facing and back-up should be completely filled with mortar. Bed joints are satisfactorily filled by spreading a thick bed of mortar and making a shallow furrow. (See previous discussion on leveling of bed joints.) The permissible length of spread of a bed joint and the resulting delay in placing the last brick will depend upon the suction (rate of absorption) of the bricks. If the suction is under 10 grams, a 3-foot (4 brick) length is satisfactory. If bricks with rates of absorption exceeding 20 grams and uncorrected by wetting are used, the length of spread of the bed joints should be reduced.

(4) The recommended procedure for filling head joints is to apply a heavy buttering of mortar on one end of the brick, press the brick down into the bed joint and push the brick into place so that the mortar squeezes out from the top and sides of the head joint. Mortar should correspondingly cover the entire side of a brick before placing as a header. Attempting to fill head joints by slushing or dashing is ineffective in securing watertight joints. Partial filling of joints by "buttering" or "spotting" the vertical edge of the brick with mortar cut from the extruded bed joint is likewise ineffective and should be prohibited. Where closures are required, the opening should be filled with mortar so that insertion of the closure will extrude mortar both laterally and vertically.

(5) Tooling of joints is not a substitute for complete filling or a remedy for incomplete filling of joints. Proper tooling helps somewhat to resist penetration by water. A concave joint is best for the purpose. Avoid, if possible, the use of raked or other joints which provide hor-

izontal water tables. Mortar should be neither too stiff nor too fluid at time of tooling since if too stiff compaction will not take place and if too fluid the bricks may be moved. In the construction of impervious masonry, bricks should not be moved after initial contact with mortar. If out of line, remove brick and mortar and lay again.

(6) Back-plastering (parging) of the back face of the exterior wythe before the back-up units are laid is recommended to help insure impermeable masonry. If the back-up is laid first, the parging should be applied to the front of the back-up. The mortar used for back-plastering should be the same as that used in laying the brick and should be applied from ¼ inch to ⅜ inch in thickness. Attempting to fill the cavity between wythes by slushing is not recommended for the reasons that slushing is unlikely to completely fill the cavity and the mortar is not compacted.

(7) Laboratory tests [28, 35, 36] have shown that plain masonry walls of concrete block or structural tile one unit in thickness, when laid with commercially practicable workmanship and without surface protection or special design, leak when subjected to treatments simulating wind-blown rain. Descriptions such as "leaked rapidly" and "highly permeable" were applied to the results of these tests. For concrete block masonry, two coats of cement-water paint [35] applied by means of stiff fiber brushes to the outside face made such walls "practically impervious as long as the paint remained in good condition." Fishburn [37] confirmed these results. Coatings such as stucco on the face or a parging of cement mortar were also effective. Properly designed and constructed cavity or grouted walls usually provide good protection from moisture penetration. The paper by Tippy [38] and its discussion, presents recommended practice in concrete masonry wall construction. Corresponding recommendations for structural clay tile masonry are given by Plummer [22]. For moisture-proofing of walls below grade see Section 6.4.

(8) An important item in the design of masonry for preventing penetration by water is the provision for adequate and properly installed flashings at vulnerable points of the wall. Reference is made to Vol. 1, No. 10, October 1950 of Technical Notes on Brick and Tile Construction (available from the Structural Clay Products Institute, 1520 18th St., N. W., Washington 6, D. C.) for recommended procedures for flashing structural clay masonry. Corresponding information on flashing of concrete masonry is presented in the 1951 Edition of the Concrete Masonry Handbook (available from the Portland Cement Association, 33 West Grand Avenue, Chicago 10, Ill). See also Appendix 11.7.

4.2.2. **Composite Walls.** Limiting the allowable compressive stress in a composite wall to that allowed for one of its vertical elements seems to be a reasonable restriction, although the results of some tests [16] under short time and concentric loading indicate an average strength somewhat higher than the strength of the weaker element. In service the portions of a wall composed of dissimilar materials may undergo unequal movements with change in temperature and moisture content and thereby cause lateral distortions and a varying distribution of stresses under constant load. However, long experience with faced walls and with structures composed of different types of masonry materials indicates that such movements are not large enough to endanger the stability of walls built in accordance with these recom-

mendations. Another reason for this requirement is the fact that the resistance of a wall to lateral loads, causing tensile stresses in the weak element of a composite wall, depends largely on the tensile strength of that element.

4.2.3. **Allowable Stresses in Plain Concrete.** See Appendix 4.2, also references [39, 40].

5.1. **Ratio of Height or Length to Thickness.** Available data [20, 40, 41] indicate that metal ties of the type specified do not have sufficient flexural rigidity to transmit shearing forces across the cavity. Consequently, when one wythe is subjected to a vertical load, only a small part of the load is transmitted to the other wythe, and the two wythes do not exert common reaction under such loading.

Although the committee is aware of the desirability of more rational methods of design than the arbitrary limitations on the ratios of wall thickness to distance between lateral supports, it was considered that more basic information is needed before they can be formulated. Quantitative data are needed on the chief factors which affect lateral stability and the resistance of walls to lateral loads. To fill this need many more tests will need to be made, some of which will provide additional information on the effects of conditions at the boundaries of walls [41].

6. **Thickness of Masonry.** This section combines the material on thickness presented in Sections 5, 6, 7, 8, 9, 11, and 12 of the 1944 edition of the standard. The requirements on bond and bonding in these sections are brought together in Section 7. The original Section 10 on veneered walls will be presented in part as a separate standard covering veneer not exceeding 1½ inches in thickness. See Section 9 of the present standard.

6.3.2. **Thickness of Nonbearing Partitions.** Section 6.3.2 replaces the table in Section 16–2 of A41.1–1944 by a uniform relation between thickness of the partition and its maximum unsupported height (or length). Inclusion of thickness of plaster as part of the thickness of the partition somewhat liberalizes the restrictiveness of 6.3.2 in comparison with the former 16–2.

If lateral support for a partition depends upon a ceiling, floor, or roof the top of the partition should have adequate anchorage to transmit the forces. This may be accomplished by the use of metal anchors or by keying the top of the partition to overhead work by mortar or otherwise. Some building codes accept suspended ceilings as providing the required lateral support. These codes (Los Angeles County Building Laws, 1953 Edition, for example) contain the additional requirement that anchorage shall be capable of resisting a horizontal force of 150 pounds per linear foot of wall. The committee has made no investigation of this matter.

6.4. **Foundation Walls.**

The importance of building basement walls and floors so that the basement area will be sufficiently dry for its intended use needs to be mentioned although this aspect is not, strictly speaking, within the scope of the standard. Foundation walls enclosing unexcavated areas generally require no special waterproofing measures but such measures frequently are deemed necessary or at least desirable with respect to basement walls and floors.

The accompanying figure 1 shows details which in the opinion of the Committee represent reasonable measures to insure a satisfactorily dry basement. The drain tile indicated in the center and right

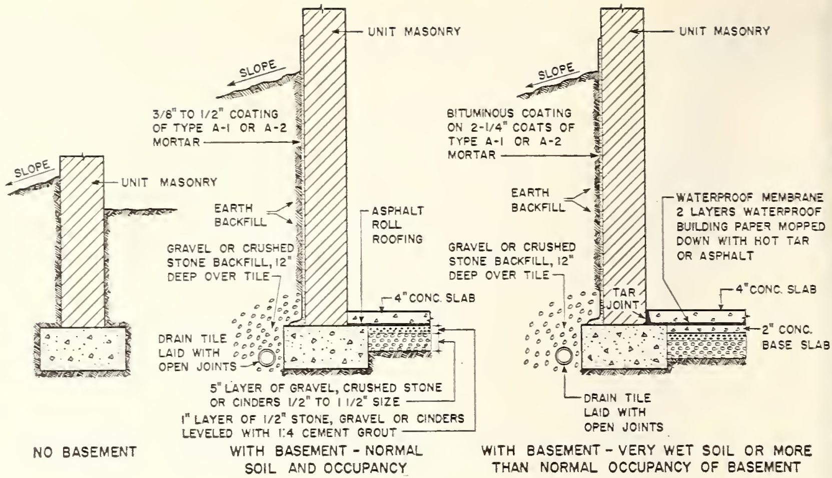

FIGURE 1. *Means of preventing entrance of water into basements.*

(Appendix 6.4.)

details of figure 1, should lead to a storm sewer or other outlet. See also paper by Fishburn [42]. With reference to basement walls of cast-in-place concrete, it is good practice to coat the outer surface with bituminous material but the plastei coatings shown in the details for unit masonry walls should not be required.

6.4.1. **Thickness of Foundation Walls.**

The committee is aware that in somewhat rare instances, foundation walls conforming to the requirements of Section 6.4 may have insufficient strength or stability to withstand the lateral pressures imposed, and that, on the other hand, the requirements may be more restrictive than needed for some structures and soil conditions. Aside from the transverse strength of the wall [14, 16, 22] (see also Appendix 4.2 and 4.2.1.), the factors which have the greatest effect upon the lateral stability of a given wall are: (1) earth pressure, (2) strength and rigidity of the lateral supports (usually the footing and the first floor above), and (3) the vertical load on the wall. The lateral pressure may be zero, or it may approach the hydrostatic pressure of a liquid having the density of mud. When backfill is by bulldozer or other heavy earth moving equipment, lateral pressure greatly exceeding the normal earth pressure may result. The probable maximum pressure for the foundation walls of a structure can be estimated closely only by those familiar with the conditions at the site.

Foundation walls of the materials and dimensions ordinarily used are not stable against earth pressures unless restrained against horizontal movement at the top and bottom or along closely spaced vertical elements. Usually the spacing of cross walls is too great for them to serve as the only lateral supports. Therefore, it is essential that the floors be so anchored and connected as to restrain the top of the wall, and that the bottom be restrained at the footing.

Vertical compressive loads on foundation walls resulting from the weight of the building and its contents tend to prevent the development of or to reduce the magnitude of the vertical tensile stresses caused by lateral earth pressures. The resistance to lateral pressures of a given foundation wall is therefore increased by an increase in the weight of the superstructure. For example, if the maximum tensile stress in the foundation wall for a one-story light wood-frame house were 20 psi, this stress probably would be reduced to 5 or 10 psi if the superstructure were changed to a typical three-story house with 8-inch brick walls. The use of thinner foundation walls for light structures than for heavy structures, as permitted by some codes, is not justified by a consideration of lateral stability.

6.4.2.1. **Foundation Walls of Reinforced Masonry.** The transverse strength of walls of reinforced masonry not only may be greater than for similar nonreinforced walls but it is also more uniform and reliable. The information available [43] indicates that 8-inch walls not more than 7 feet deep reinforced with ⅜-inch round bars 2 feet apart, or the equivalent in smaller bars or wires, has adequate resistance under the conditions commonly encountered. The heights of the backfill against other types of 8-inch walls of unit masonry are limited to values related to their expected resistance to lateral pressures.

6.5. **Parapet Walls.**

The provisions of this section are intended to regulate only the structural features of parapet walls. Other standards in the series of American Standard Building Code Requirements will specify when parapet walls are required.

The limits on the ratios of height to thickness of parapet walls specified in this section are believed to be safe for ordinary conditions. In localities subject to high winds or to earthquakes, somewhat more rigid restrictions may be advisable.

Particular attention should be paid to the flashing, dampproofing, and workmanship of parapet walls to prevent disintegration. Through flashing should be provided under the coping, unless the coping is of an impervious material laid with water-tight joints, and also at the base of the wall. All joints should be well filled. Coating, or sealing of the back of the wall with vapor impermeable materials is not recommended, as this practice prevents rapid drying of the masonry.

7.1.2. **Bonding With Metal Ties.** Figure 2 illustrates the staggering and spacing of metal ties according to the requirements of 7.1.2.

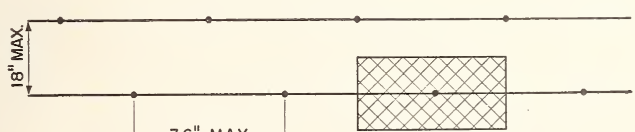

Figure 2. Spacing and staggering of metal ties.

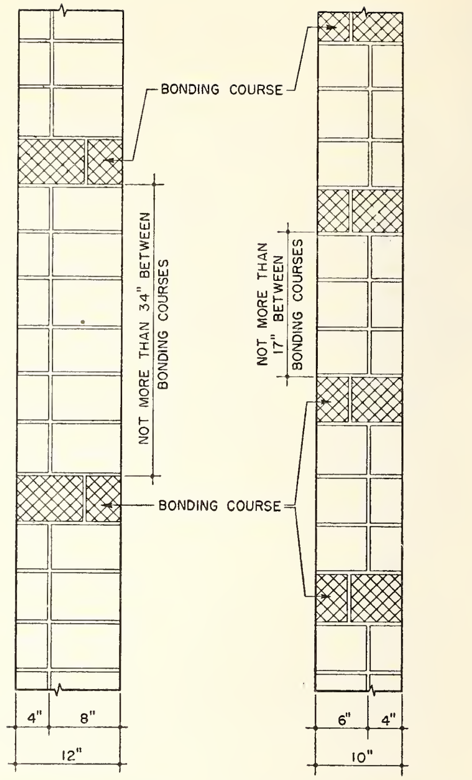

FIGURE 3. *Types of bonding with hollow units.*

7.2. **Bonding of Masonry Walls of Hollow Units.** Figure 3 illustrates the type of bonding prescribed by 7.2.1.

7.7.4. **Bonding of Nonbearing Intersecting Walls.** Building codes and construction practice allow considerable latitude regarding the bonding or anchorage of ordinary interior nonbearing walls with intersecting walls or structural members. When built solidly against floor and ceiling such partitions usually should derive sufficient lateral bracing from these contacts. However, if the wall separates from the ceiling due to settlement, contraction, or other causes, its lateral stability will be impaired and made more dependent on its connections with other members. For this reason bonding or anchorage with intersecting walls and members seems desirable. A few suggested details are shown herein (fig. 4) but there are various other details which would be equally satisfactory and acceptable.

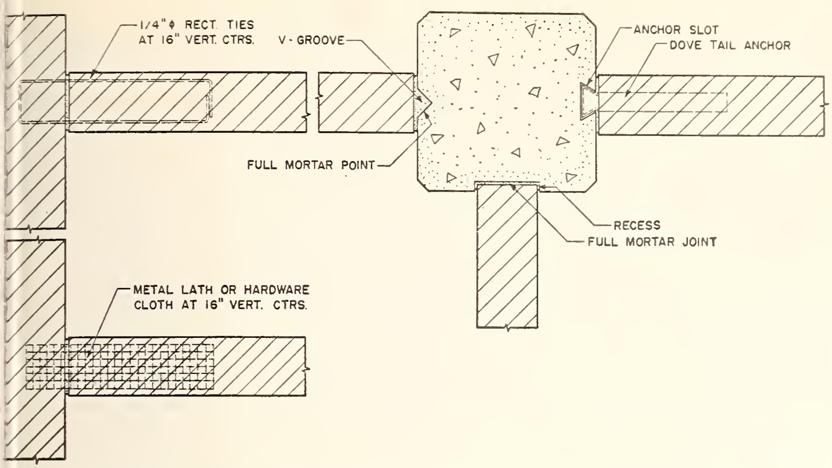

FIGURE 4. *Examples of bonding or anchorage of nonbearing walls.*

Regarding nonbearing walls which function as curtain walls, panel walls, fire walls, or shear walls (walls affording lateral support) it is ustomary and good engineering practice that they be bonded or nchored with intersecting walls and structural members in a a manner ssuring adequate resistance to the design lateral forces acting on the onnection.

11.1.2. **Fastening Joists or Beams.** All floor beams should be dequately anchored to the masonry wall and to each other. Anchors f iron or steel, or other suitable metal, for floor joists should be proided at 4 foot intervals where floor joists are supported on masonry valls. They should engage not less than half the thickness of the vall and should be solidly embedded in mortar. Interior ends of nchored joists should be lapped and spiked, or the equivalent, so as o form continuous ties across the building.

11.1.3. **Spacing.** Anchors tying walls to joists parallel to the vall should engage not less than three joists. They may be inserted hrough holes near mid-depth of the joists.

11.1.4. **Anchoring Structural Members.** Examples of adequate nchorage are presented in Factory Mutual Bulletin of Loss Prevenion No. 7.13, "Anchorage of Factory Roofs" [44].

11.2.1.1. **Chases and Recesses—Exceptions for 8-inch Walls.**— The exception to the usual requirement that there shall be no chases n 8-inch walls is made to provide for ducts of warm-air heating ystems in dwellings and for the recessing of radiators under windows. ince the grilles must be located in exterior walls in many cases, and nce the 8-inch wall is the common practice in dwellings, it was eemed necessary to provide space in the wall for the elbow of the uct where it makes the turn from the grille to the branch line located etween the floor joists. The committee was of the opinion that hases of the dimensions permitted in this section would not weaken he wall to any serious extent and would permit of some economy nd convenience in the installation of the heating system. As no

load of any importance is carried by the masonry under the window sills, it was felt that recesses for radiators could safely be permitted under the conditions set forth in this section.

11.7. **Drainage of Hollow Walls.** The following is quoted from the Structural Clay Products Institute leaflet on Cavity Walls (Technical Notes on Brick and Tile Construction, Vol. 1, No. 6, June 1950):

> *Draining the cavity.* It is important that the cavity be kept clear of mortar droppings during construction and that the mortar is not permitted to bridge the air space between wythes. The bottom of the cavity should be located above ground level, and the cavity should be drained by weep holes in the vertical joints of the bottom course of the outer wythe. The weep holes, spaced approximately 2 feet apart, may be formed by leaving an open vertical joint between units in the bottom course, or by other suitable methods.
>
> *Flashing.* Good flashing details are particularly important in cavity wall construction. Flashing should be installed over all wall openings, not protected by projecting eaves or hoods, to deflect moisture outward through the outer wythe. The flashing should extend 6 inches beyond the jamb on each side of the opening, and weep holes provided to drain any accumulated moisture. Continuous flashing should be installed at the bottom of the cavity to deflect any accumulated moisture to the outside through the weep holes. Where there is no basement, however, and the bottom of the cavity is above ground level and several inches below the lowest bearing level of the first floor, no flashing need be provided, but a damp-course should be placed in both the inner and outer wythe, one course above the bottom of the cavity and below the bottom of the first floor joists. Where unit masonry sills are used, flashing is advisable under the sills, and weep holes should be provided.

11.8.2. **Walls of Insufficient Thickness.** Type A–1 mortar is required for masonry added to existing walls to insure that the modulus of elasticity of the new masonry will not be excessively low in comparison to that of the existing masonry. The modulus of elasticity of the masonry tends to increase with age. Furthermore, the original masonry may be assumed to have undergone its maximum decrease in height from loading. A high modulus of elasticity of the new mortar would therefore lessen the probability of failure of bond between the old and new masonry through shear resulting from shortening under load.

11.9.1. **Bracing to Resist Lateral Loads.** Section 19–3 of the 1944 edition of the standard required that "Except when carried independently by girders at each floor, no wall shall be built up more than 25 feet in height in advance of other walls of the building" and 19–6 of the same standard prescribed "During erection, walls shall be adequately braced." Section 11.9.1 sets the limit in terms of height with respect to thickness beyond which bracing is required. Justification for this requirement is given in the article by Sweet [45] "Resistance of brick walls to wind."

11.9.2. **Wetting of Brick (Clay or Shale).** The great importance of the suction rate of the masonry unit and the consistency (flowability) of the mortar on the tensile strength and watertightness of masonry has been demonstrated conclusively [19, 20, 22, 28, 34].

The flowability of the mortar should be the maximum compatible with efficient use by the mason, and additional water should be added if needed to overcome the stiffening resulting from evaporation of some of the mixing water. Suction rates of clay or shale brick should be ascertained in advance of their use in construction. Methods of measurement may be similar to those used in specifications [33], but the following methods may be found more practicable in some instances. A rough but effective test for determining what bricks give improved bond by wetting consists in sprinkling a few drops of water on the flat of the brick and noting the time required for these drops of water to be absorbed completely. If this time exceeds 1 minute, wetting is not needed. A refinement of this method consists in drawing a circle 1 inch in diameter on the flat of the brick with a wax pencil (using a 25-cent piece as a guide provides a circle of almost the exact dimension). One milliliter of water (20 drops) is applied to the surface thus limited and the time for complete absorption is noted [46]. If this time exceeds 1½ minutes, the bricks need not be wetted; if less than 1½ minutes, wetting is recommended.

Wetting of vitrified and semivitrified bricks or excessive wetting of other bricks is undesirable because of resultant floating of the bricks and "bleeding" of the mortar. A satisfactory procedure consists in playing a stream of water on a pile of bricks until water is observed to run from each individual brick visible in the pile. Unless the bricks are exposed to conditions favoring the rapid evaporation of moisture, one wetting per day is sufficient.

11.9.3. **Protection Against Freezing.** The cold weather requirements for reinforced concrete given in Section 406 of Building Code Requirements for Reinforced Concrete, (ACI 318–51; ASA A89.1–1951) would apply in general to masonry. The use of calcium chloride (the dry salt) in an amount not exceeding 2 percent by weight of the portland cement content of the mortar is permissible. If used, dissolving of calcium chloride in the mixing water is recommended. The effect of calcium chloride is to accelerate the setting and hardening of the portland cement in the mortar. The lowering of the freezing point by this material in the amount permitted is negligible. Addition of salts such as sodium chloride (common table salt) should not be permitted since they will cause efflorescence and may disintegrate the masonry by recrystallization.

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